HYDROLOGIC STUDIES ON A SEEPY AREA IN THE TEXAS BLACKLANDS

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CONTENTS

HYDROLOGIC STUDIES ON A SEEPY AREA IN THE TEXAS BLACKLANDS[1]

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SUMMARY

A research project has been established at the Blacklands Experimental Watershed near Riesel, Texas, to (1) determine the feasibility of subsurface drainage of localized seepy areas, and (2) obtain data for documenting hydrograph separation techniques. Rainfall, ground-water depths, surface runoff, and ground-water flow are being observed on the study area.

A seepy area in a terraced field at the Blacklands Experimental Watershed often prevented normal farming operations. Structures were planned to drain the area and at the same time provide research information on hydrologic characteristics. Excavations, structures, and instruments were installed for measuring and recording rainfall, surface runoff, subsurface flow, and ground-water level. Methods were worked out for analyzing the data to be obtained.

Although no large body of data has yet been collected, data from the first storm after installation of all equipment indicated that this project will provide a practical test of current methods of separating base flow from surface flow in hydrographs. As subsequent data are collected, methods will be further developed and refined.

INTRODUCTION

The Blacklands Experimental Watershed lies near the center of the main Blackland Prairie in the Gulf Coastal Plain (fig. 1). This prairie consists of about 9,000,000 acres in a northeast-southwest band across Texas.

The Blackland Prairie of Texas has no regional aquifer. However, some water is perched above the clay or marl layers underlying much of the blacklands. During prolonged rainy periods, the perched water table rises until it surfaces at the chalk or marl outcrops.

One such seepy area lies in a terraced field at the Blacklands Experimental Watershed. Measures necessary to correct this problem were recognized as an opportunity to conduct hydrologic research.

A trench constructed to drain the seepy area was designed and instrumented to measure the ground-water flow. The addition of a weir to measure the surface flow from a part of the same contributing area completed the experimental setup needed to observe the amounts and time distribution of the two flow components.

Currently, in the analysis of hydrographs, separation of the base flow from the surface flow is based on simplifying assumptions, none of which have been tested. In this experiment, observations of the ground-water and surface flow characteristics will provide data needed to test the assumptions, or to lead to the development of a rational method for separating base flow from surface flow.

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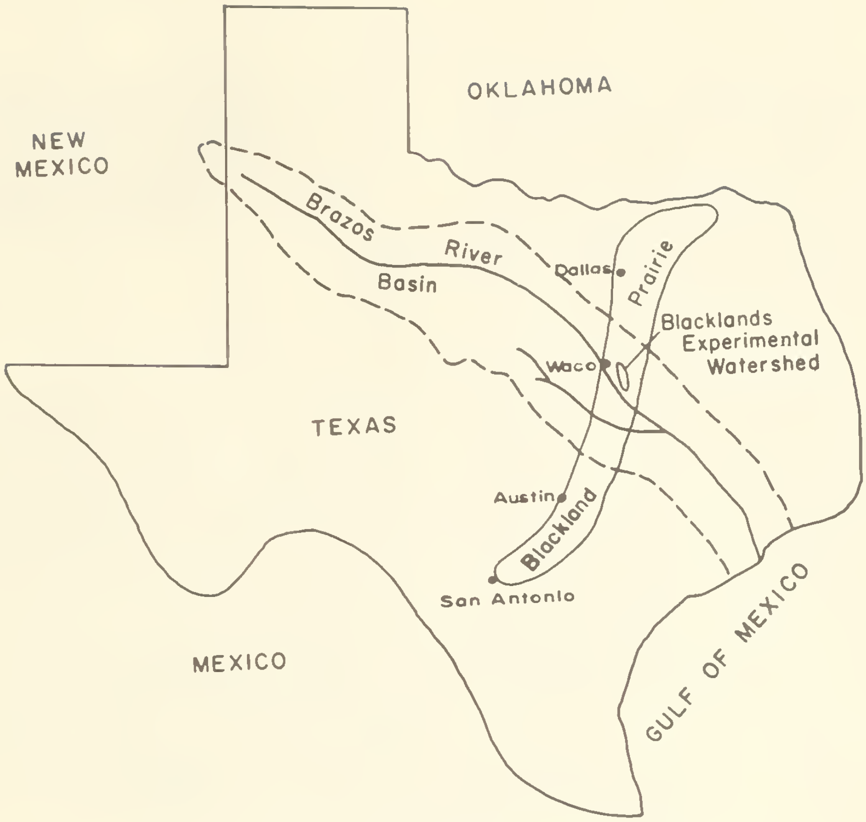

Figure 1.–Location of Blacklands Experimental Watershed.

GEOLOGY

The geology, topography, and soils of an area directly affect its ground-water distribution and movement. The specific location within the topographic and geologic area is important because differing conditions at the boundary may impose restrictions on quantitative and qualitative results within the edge of the area.

The relief of the Blackland Prairie is gently rolling to nearly level. The prairie developed from geologic material of the Cretaceous system.[3] [4] The major groups, from oldest to youngest, are the Eagle Ford, the Austin, the Taylor, and the Navarro. The Eagle Ford appears in only a small part of the main prairie. Each group includes several formations varying in characteristics. The Taylor, most extensive of the three groups, underlies the Blacklands Experimental Watershed. Only this group will be described.

The Taylor is dominantly marl, but also includes strata of sand and chalk. In the watershed area, the members of the Taylor dip approximately 80 feet per mile in a direction about S. 75° E. The two general members of the Taylor in the watershed, in ascending order, are Wolfe City sand (sandy marl) and Pecan Gap chalk. Four formations can be distinguished in the Pecan Gap chalk. They are, in ascending order, (1) lower chalk, (2) lower highly calcareous marl, (3) upper chalk, and (4) upper highly calcareous marl.[5]

Soils developed from the previously described Cretaceous formations are dominantly Houston Black clay over marl or chalk. Depths of soils vary, but those overlying marl are generally deeper than those over chalk.

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[3] Baird, R. W., Lauritzen, C. W., Stewart, A. J., and others. The agriculture, soils, geology, and topography of the Blacklands Experimental Watershed, Waco, Tex. USDA Hydrol. Bul. No. 5, 38 pp. 1942.

[4] Blank, H. R., Stoltenberg, N. L. and Emmerich, H. H. Geology of the Blacklands Experimental Watershed, near Waco, Texas. Bureau of Econ. Geol., Univ. of Texas, Austin, Tex. Rpt. of Invest., No. 12, 46 pp. 1952.

[5] See footnote 4.

CLIMATE

General climate of the Blacklands is subhumid.[6] The average annual rainfall at the Blacklands Experimental Watershed is 33.25 inches. Approximately one-third of the annual rainfall occurs in April, May, and June. July is the driest month. The distribution varies considerably from the normal pattern. Normally, the spring rains are more than sufficient to fill the soil moisture reservoir and thereby produce surface runoff. Soil moisture is generally depleted to low levels by crop production during the summer. The fall rains again largely fill the soil moisture reservoir. Winter rains, although normally light, frequently maintain high moisture conditions until spring.

DESCRIPTION OF THE STUDY AREA

A seep existed in a cultivated field on the Blacklands Experimental Watershed when a conservation program was begun in 1943. To prevent a large surface area of the field from remaining wet for long periods, a channel-type terrace was constructed immediately downslope from the seep outcrop. The terrace channel collected the water that appeared at the surface and carried it into the terrace outlet. The problem was only partly solved, because a large area of terrace channel and ridge was wet for long periods, damaging crops and encouraging the growth of undesirable vegetation.

Late in 1966, after two successive "wet" years, plans were made to construct a subsurface drain to carry excess water out of the area. Measurements of seepage flow at the terrace outlet with a portable V-notch weir during 1965-66 showed that the volume of water was small. The water level in an observation well[7] during the same period showed ready response to storm influences. Therefore, it was believed that effective drainage could be attained with a trench. Subsurface flow could then be readily measured at the trench outlet.

Topographic and geologic data were available for the area around the seep.[8] Figure 2 shows the topography of the area, which is typical of the Blacklands in general. Using a dip of 80 feet per mile in a direction S. 75° E. as previously mentioned, the suspected ground-water-

[6]United States Department of Agriculture. Climate and man. U.S. Dept. Agr. Yearbook 1941. 1,248 pp. 1941.

[7]Potter, W. D. and Blank, H. R. Blacklands Experimental Watershed ground water graphs, 1936-67. U.S. Dept. Agr. SCS-TP-24, 21 pp. 1939.

[8]See footnotes 3 and 4.

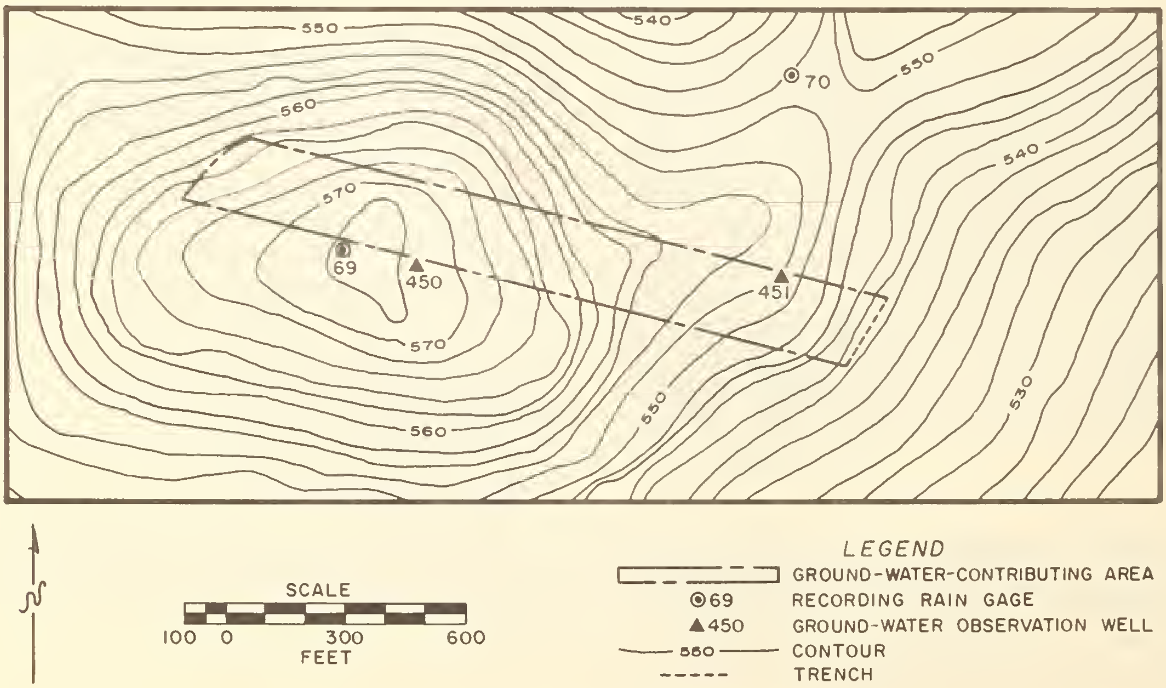

Figure 2.–Topographic map of the study area.

contributing area was projected up dip from the planned subsurface drain. The projected area and line of trench is shown in figure 2. The ground-water-contributing area, 7.8 acres in size, was determined entirely from topographic and geologic data.

A geology map of the same area shown in figure 2 was used to determine the outcrops relative to the suspected ground-water-contributing area. Figure 3 shows that the contributing area boundary coincided with the Pecan Gap lower chalk outcrop. The agreement between topographic and geologic boundaries was good.

Surface features of the study area are shown in figure 4. The terrace affected by the seep is T-3 in field 9 (fig. 4). Auger samples were taken along the upper side of the terrace channel where effects of the seep were evident, to determine the length and depth of drain trench required. The samples indicated a profile very similar to that shown in figure 5. Although no water was seeping into the terrace channel at the time of sampling, free water entered the holes at varying depths. The water was apparently being transmitted within the light-colored zone shown in figure 5. To intercept the water, a trench 5 feet deep was needed. The wet terrace channel and auger samples indicated that the trench should extend approximately 200 feet into the field from the road.

A gravel-filled trench was deemed adequate for satisfactory drainage. However, since drainage was only a part of the project, and measurement of ground-water flow was planned, entry of overland flow into the gravel was objectionable. Locating the trench upslope from the terrace channel and covering the gravel with topsoil were considered sufficient preventive measures.

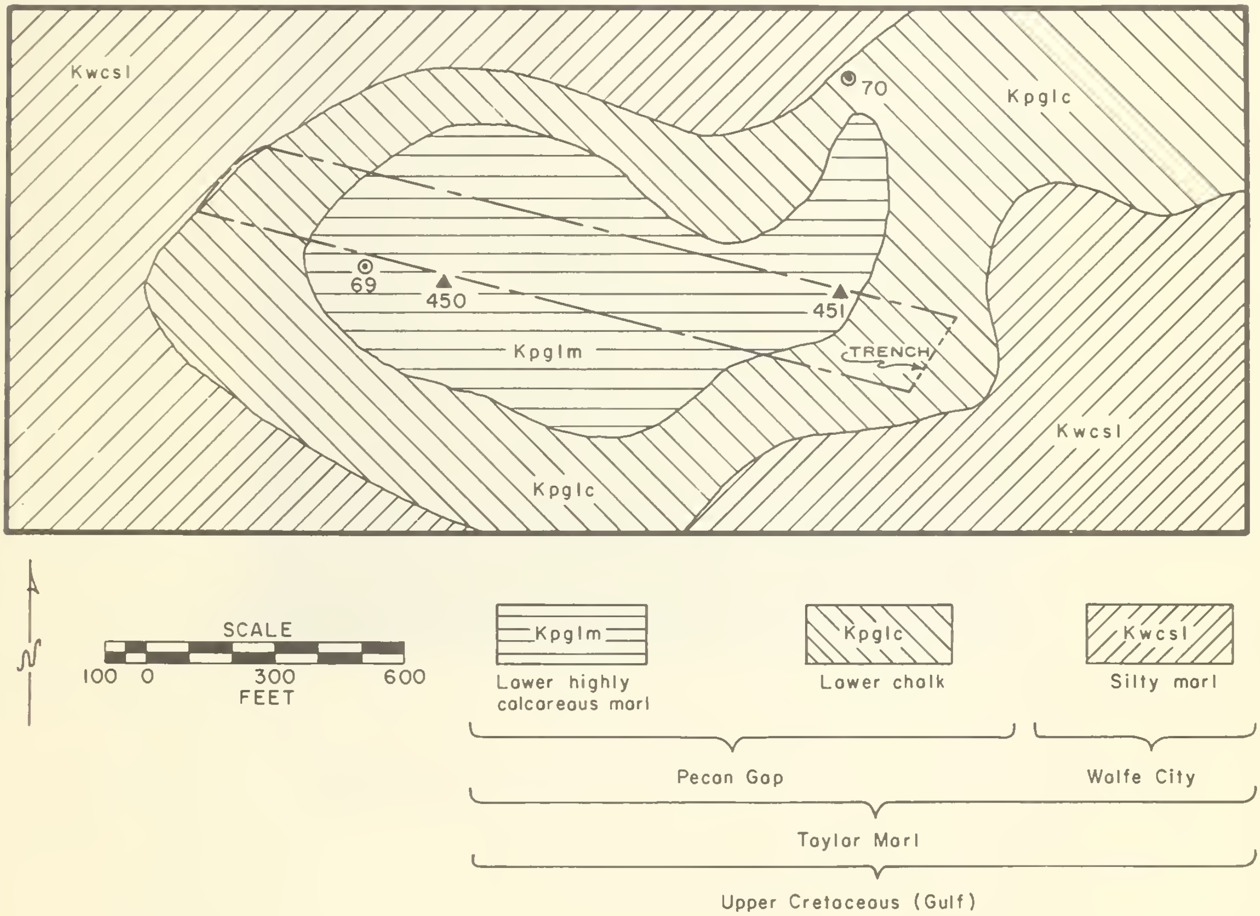

Figure 3.–Geology map of the study area.

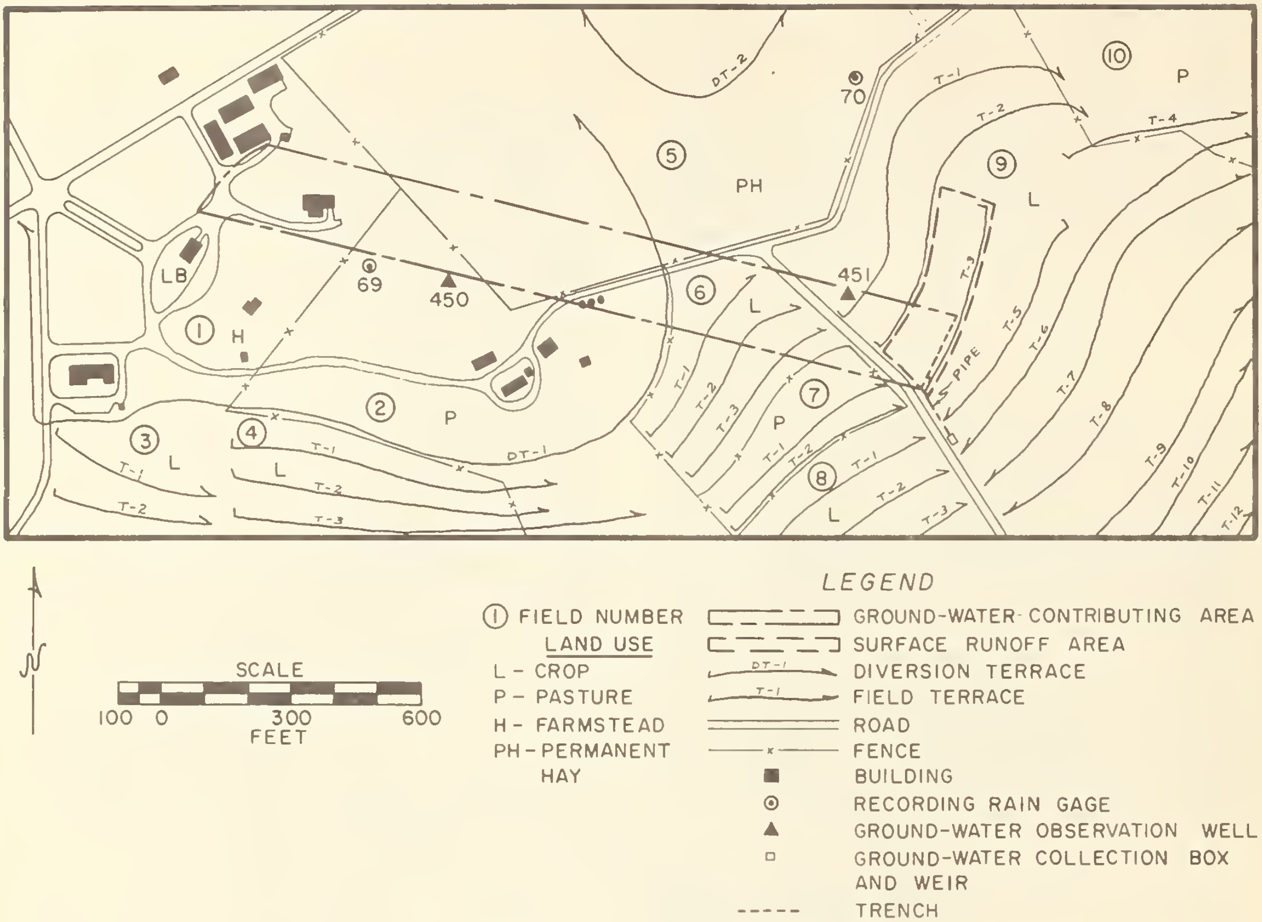

Figure 4.–Surface features of the study area.

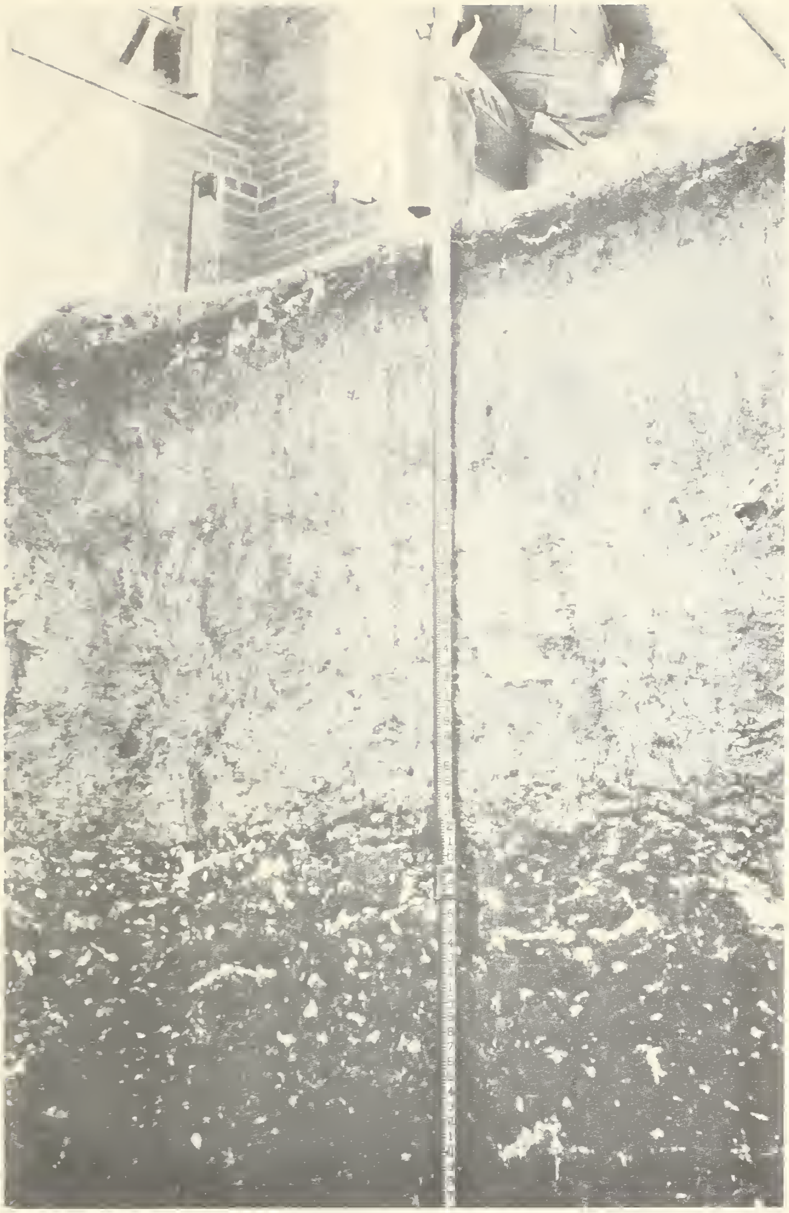

Figure 5.–Contact of Pecan Gap chalk (above) the Wolfe City silty marl (dark, below), showing soft white calcium carbonate leached from the chalk and deposited in crevices in the marl.

A backhoe was used to excavate a trench 1-1/2 feet wide by 5 feet deep by 200 feet long. The trench was backfilled with 3 feet of washed gravel that ranged from 1/4 inch to 1-1/2 inches in diameter. A layer of building felt was placed on top of the gravel, and the top 2 feet of the trench were backfilled with topsoil. The felt was used to prevent soil from migrating into the gravel, and also as an additional barrier for surface runoff. Details of the drain are shown in figure 6.

A metal collection box with a screened front and a pipe outlet on the side was placed at the end of the gravel-filled trench to receive the flow. Tile was installed from the pipe outlet to carry the water from the trench to a measuring device at the surface downslope (fig. 4).

The measuring device is a 90° V-notch weir 6 inches deep in the side of a stilling tank. A water-level recorder provides a continuous measurement of head on the weir. Figure 7 is a photograph of the installation in operation. The collector box, drain pipe, and ground-water measuring device were installed before digging the trench. Thus, recession-flow data and well observations were obtained during excavation of the drain trench as water continually drained out of the upstream sidewall.

To obtain surface-runoff data for comparison with ground-water hydrographs, a Cipolletti weir was installed at the outlet of the terrace. The weir installation with water-level recorder is shown in figure 8. The weir was constructed with an 8-inch depth and 3-foot crest. This size is sufficient to accommodate the surface drainage from the 1.3-acre delineated in figure 4. The Cipolletti weir, with continuous water-level measurements, will accurately define times of rise and peak, and will provide acceptable data for runoff volume. Water-level measurements of the Cipolletti and V-notch weirs provide timing

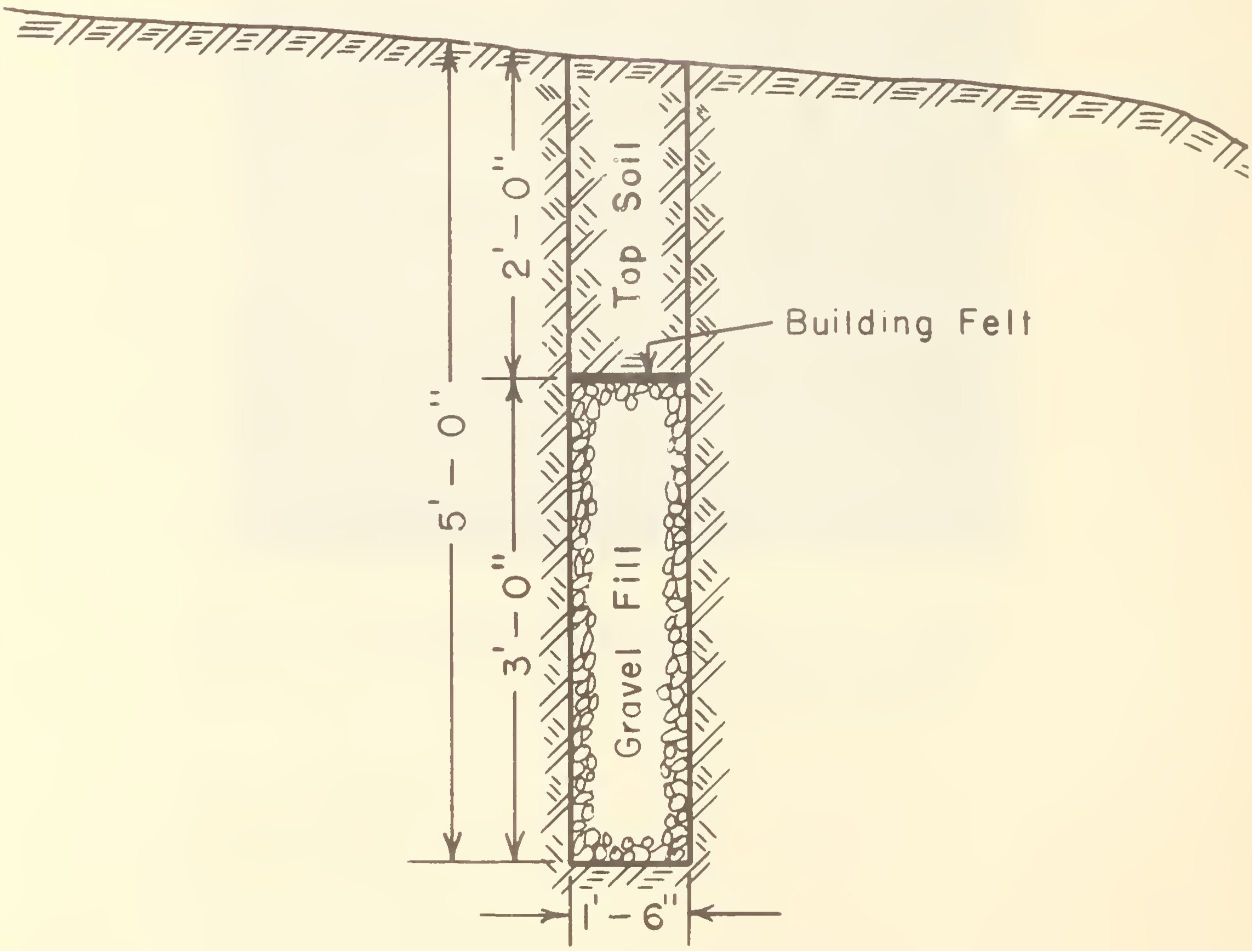

Figure 6.–Schematic drawing of drain trench details.

characteristics for hydrograph analyses. Continuous records of ground-water levels are obtained at two observation wells up dip from the drain trench. Rainfall is also measured at two locations in the area. Locations of the wells and rain gages are shown in figures 2, 3, and 4.

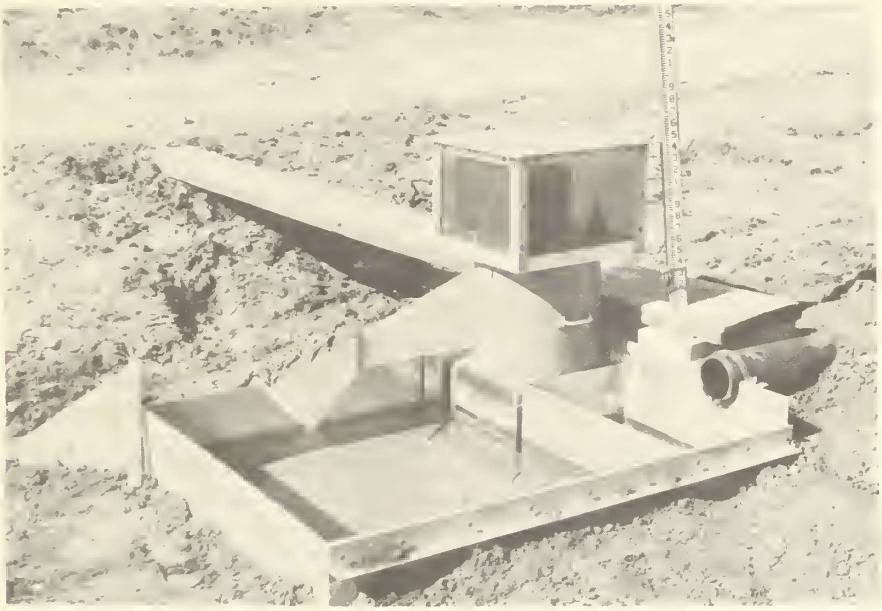

Figure 7.–Installation of 90° V-notch weir for measuring ground-water flow.

Figure 8.–Cipolletti weir installation for measuring surface runoff.

DELINEATION OF GROUND-WATER-CONTRIBUTING AREA

Certain assumptions were made in the delineation of the ground-water-contributing area. The upper end boundary was determined from amount of dip and outcrop of stratum, and is relatively exact. However, the side boundaries, which were determined by projecting up dip from the ends of the drain trench, are not exact, and drainage from outside these bounds would be expected.

There is evidence that the contribution from outside the projected boundaries is negligible. The water surface in well No. 451, located inside the contributing area, declined during excavation of the drain trench. However, water continued to stand in a low place in terrace channel T-1 in the field 7 pasture (fig. 4). If drainage had occurred from outside the contributing area, the pool in field 7 would have been affected. Further study of the contributing area is being planned. A Hele-Shaw viscous-fluid model study[9] will be made to determine the side drainage effects.

The ground-water-contributing area boundaries do not coincide with those of the surface drainage area. This is not of concern and will not affect the applicability of results, since ground-water and surface-water divides seldom, if ever, coincide on drainage basins.

PRELIMINARY DATA

The first runoff-producing storm after the installation was completed occurred on April 13, 1967. This storm is used as an example to show the characteristics of the surface and subsurface flows and water-table behavior.

The weir for ground-water flow measurement was installed January 23, 1967. Daily rainfall, water-table elevations, and mean daily ground-water flow are shown in figure 9. Ground-water flow receded continually until the April storm. The 2.22 inches of rainfall on April 13 caused 7.6 feet of rise at well No. 451, with only a slight, delayed rise at well No. 450. Ground-water flow increased considerably as indicated in figure 9.

Figure 10 shows the observed hydrographs of surface and ground-water flow, well hydrograph, and rainfall distribution for the storm. The first 1.25 inches of rain had the highest intensity. However, the dry soil at the beginning of the storm abstracted most of the rainfall, and little surface runoff occurred. The figure shows that the water level in well No. 451 did not rise until after the early rainfall ended. However, an increase in ground-water flow was observed soon after the onset of the rain, and the rate decreased as the rainfall intensity decreased. The increased ground-water flow probably resulted from overland flow entering the drain trench. The surface-soil fill on the drain trench had been packed when relatively dry, and probably it had not consolidated sufficiently to prevent a small amount of overland flow from entering the drain. This reasoning is supported by the fact that the ground-water peak occurred before the surface-flow peak in the early period.

Soil water was transmitted to ground water quickly, and the well began to respond shortly after the initial rainfall ended. Records for the latter part of the storm indicated good operation for all components. Overland (surface) flow began shortly after rainfall started for the second time. Ground-water flow did not increase until after surface flow began. During this part of the storm, the surface flow peaked at hour 0512, the water table leveled off at 0600, and the ground-water flow did not peak until 0636. The relative times of peak of the two hydrographs agree with physical reasoning. Ground-water velocities are lower than overland flow velocities; therefore, the ground-water peak would occur later. Since ground-water flow decreased only slightly during the following days (fig. 9), surface flow apparently did not enter the drain. The water level began to drop at hour 1500 on April 13. The elevation shown in figure 9 on that date represents the peak.

Surface runoff ended at 0945 on April 13. A total hydrograph for the storm period was constructed by adding the discharge for the surface-water and ground-water components (fig. 10). Because the contribution from ground-water flow was insignificant during the rise of the hydrograph, the total hydrograph is shown only for the recession. Surface runoff for the entire storm period was 0.464 inch equivalent depth over the 1.3 acres of surface drainage, or 2190 cubic feet. Ground-water flow for the same period was approximately 240 cubic feet, or approximately 10 percent of the total flow. This 240 cubic feet is only for the storm period to the end of surface flow.

One storm event is certainly not a broad enough basis for conclusions, but the hydrograph characteristics are noteworthy. Linsley, et al.[10] noted three arbitrary methods of base-flow separation. The method most

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[9] Todd, D. K. Ground water hydrology. John Wiley and Sons, New York, New York, 336 pp. 1959.

[10] Linsley, R. K., Jr., Kohler, M. A., and Paulhus, J. H. Hydrology for engineers. 340 pp. McGraw-Hill, New York. 1958.

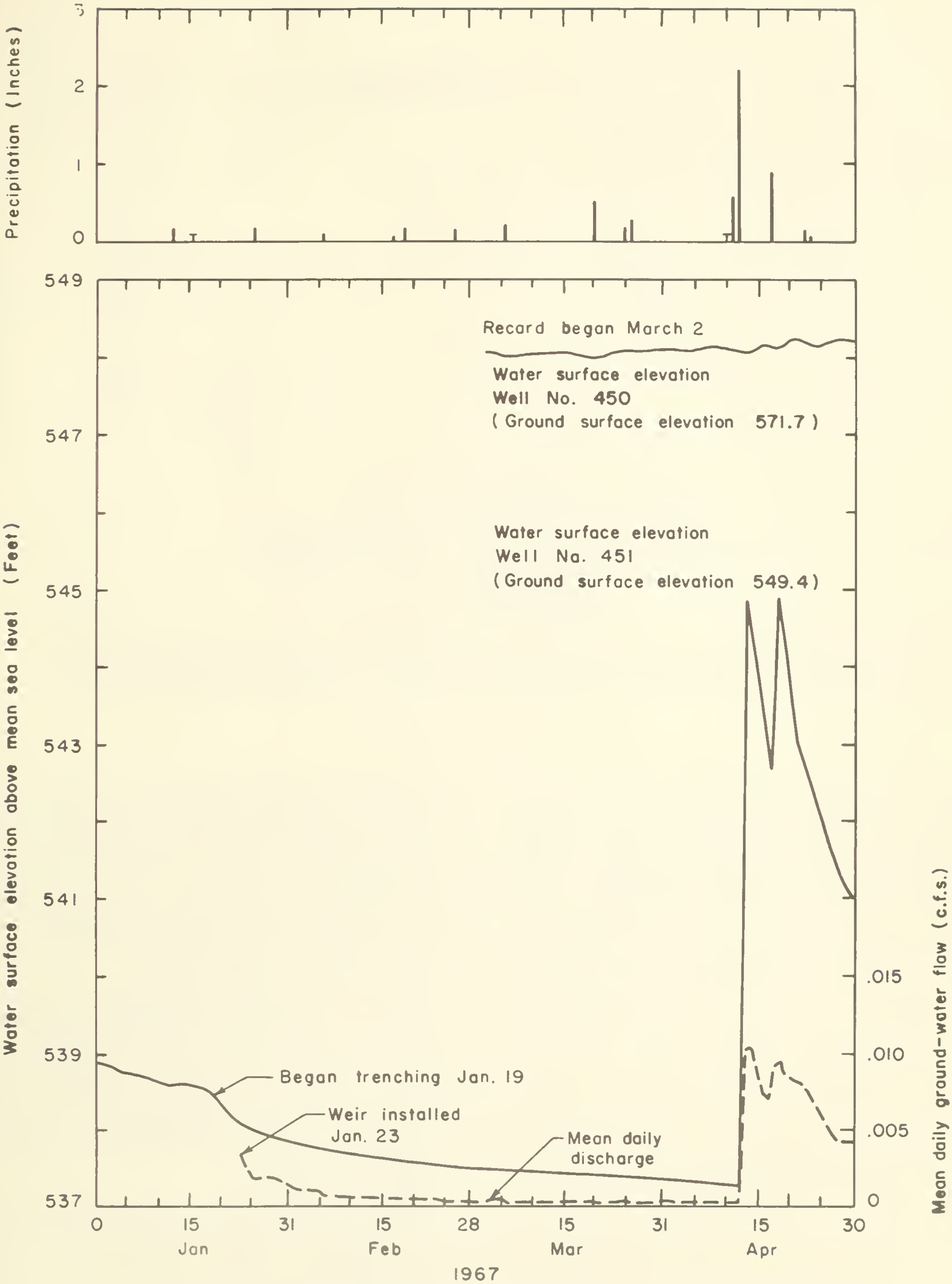

Figure 9.–Ground-water hydrographs for wells number 450 and 451, and mean daily ground-water flow. Precipitation at rain gage 70.

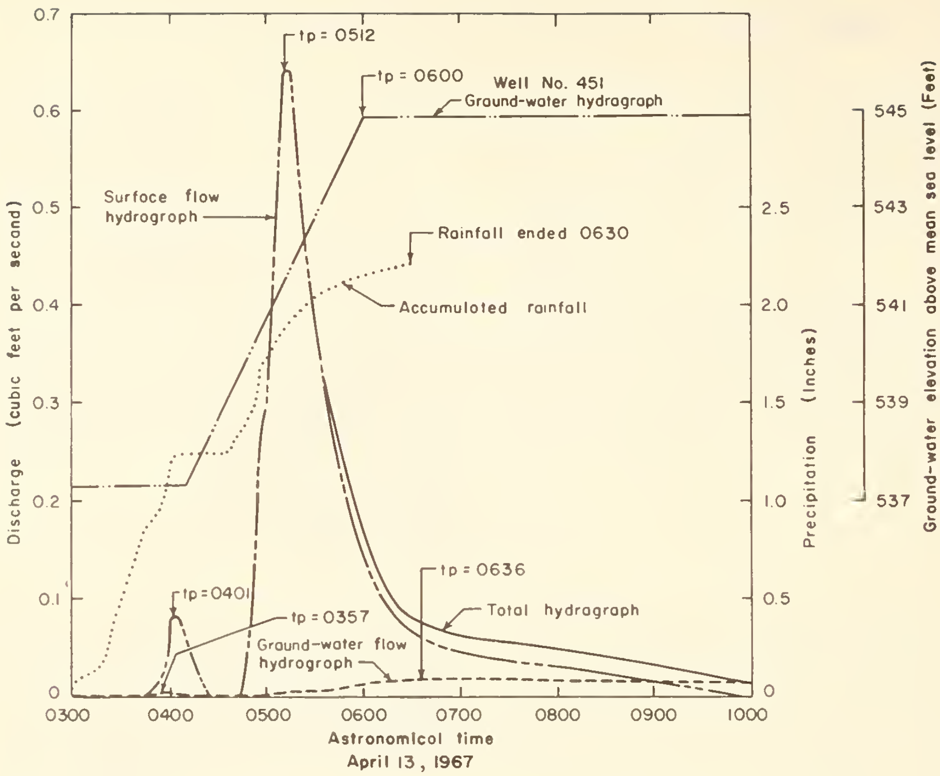

Figure 10.–Surface, ground-water, and composite discharge hydrographs, ground-water well hydrograph for well No. 451, and accumulated rainfall for storm of April 13, 1967. Time of peak flow (tp) indicated in astronomical time.

widely used requires projection of prior base flow to a point under the hydrograph peak, thence increasing to a base-flow peak at an aribitrary point on the recession. Another method projects the ground-water recession, after the storm, back under the hydrograph to a point under the inflection point of the falling limb. An arbitrary base-flow rise is then drawn from the beginning of hydrograph rise. Linsley indicated that little accuracy is gained by either method. The observed hydrographs presented in this paper indicate the first method is erroneous, but they compare reasonably well with results of the latter method. The relative volumes of the two flow components indicate that base flow is a small percentage of the total. The observed 10 percent cited previously for the small storm would be near maximum.

Further indication of the significance of ground-water flow in the Blackland Prairie can be seen in the recession data. Ground-water flow from January 23 through April 12, expressed as equivalent depth over the contributing area, was 0.167 inch. During this same period, the water level in well No. 451 declined 0.84 foot. Assuming a uniform thickness of saturated soil, the equivalent storage would be 0.017 foot per foot of depth. Since well No. 450 essentially did not respond, the area actually contributing to the ground-water recession flow was less than the 7.8-acre hypothesized area. If the contributing area in this case was only one-half, the storage would be only 0.034 foot per foot of depth. Since water-transmitting strata are of limited area in the Blackland Prairie, it is readily seen that ground water is of little significance for water supply.

Mean daily ground-water discharge for the short period of record is a subdued replica of the observation well hydrograph. There appears to be a relation between mean daily discharge and depth of water in the observation well above the bottom of the drain. Depth of water and horizontal distance between the well and drain represent the hydraulic gradient under which the ground water is flowing.

As data become available, ground-water and surface water hydrographs will be combined by addition. Hydrograph characteristics will be studied to develop separation techniques for surface flow and base flow. The developed techniques will be tested by comparing separated and observed hydrographs.